NACA RM E52L22

C 2

RESEARCH MEMORANDUM

EFFECT OF DRAWBAR UPSTREAM LOCATION ON AIR VELOCITY DISTRIBUTION AT THE INLET FACE OF REACTOR SEGMENT DESIGNED BY THE GENERAL ELECTRIC COMPANY

By T. F. Nagey and E. W. Sams

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

January 1953

Declassified April 1958

2769

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

EFFECT OF DRAWBAR UPSTREAM LOCATION ON AIR VELOCITY DISTRIBUTION AT THE INLET FACE OF REACTOR SEGMENT DESIGNED BY THE GENERAL ELECTRIC COMPANY

By T. F. Nagey and E. W. Sams

CD-1

SUMMARY

An investigation was conducted at the NACA Lewis laboratory on a drawbar, for the General Electric reactor segment tests in the Materials Testing Reactor. The drawbar is essentially a hollow T-shaped body, located upstream of and fastened to an air reactor test segment to facilitate insertion and withdrawal of the test segment from the reactor and to provide a protective cover for instrument leads. This investigation was undertaken to determine the effect of drawbar upstream location on air velocity distribution at the reactor inlet face.

Velocity distributions were obtained over a range of equivalent reactor-inlet Reynolds numbers of about 35,000 to 100,000 with inlet-air pressures up to about 34 inches of mercury absolute and ambient inlet-air temperature. The distances between drawbar and pitot-static tube (representing reactor-inlet face) at which velocity surveys were taken were varied from about 3 to 5 inches; for comparison, velocity surveys were also taken with the drawbar removed from the tunnel.

The results of these tests, for an equivalent reactor-inlet Reynolds number of about 100,000 and a drawbar-to-probe distance of about 3 inches, indicate that the ratio of local to bulk velocity at the center of the reactor segment face decreased about 8 percent from the corresponding value found with the drawbar removed. As Reynolds number increased from about 35,000 to 100,000, for a given drawbar location, the ratio of local to bulk velocity at the center of the segment face decreased only about 1 percent.

INTRODUCTION

The General Electric Company is constructing an air-cooled reactor for aircraft propulsion. A small rectangular segment of this reactor has been built by General Electric for preliminary "in-pile" tests in the Materials Testing Reactor. For these in-pile tests, a drawbar must be placed immediately upstream and across the center line of the air-inlet face of the reactor segment to facilitate insertion and removal of the segment from the reactor and to provide a protective channel for instrumentation leads. The drawbar is a T-shaped metal tube (fig. 1(a)). The handle end is about 14 inches long and has an outside diameter of 0.5 inch. The cross member is 2.4 inches long and has an elliptical cross section with major and minor diameters of 0.625 and 0.375 inch, respectively, the minor diameter being normal to the air flow direction.

In order to keep the lead shielding weight requirements to a minimum for the in-pile tests, it is desirable that the drawbar be placed as close to the upstream face of the reactor segment as is possible (fig. 1(b)) without causing a serious maldistribution of air flow across the inlet face of the test segment. The present investigation was undertaken at the Lewis laboratory to determine the effect of several drawbar-to-reactor inlet distances on velocity distribution at the reactor inlet face. For these tests, the drawbar was constructed of wood, and a pitot-static tube was used for making velocity surveys at several points downstream in a simple wood tunnel built for these tests (fig. 1(c)).

The tests were conducted over a range of equivalent reactor-inlet Reynolds numbers from about 35,000 to 100,000 with inlet-air pressures up to about 34 inches of mercury absolute and ambient air temperature. The results of these tests are presented herein in the form of plots of the ratio of local to bulk velocity against distance of the probe from the tunnel wall for a range of drawbar-to-probe (reactor-inlet face) distances.

EQUIPMENT AND INSTRUMENTATION

Drawbar. - Figure 1(a) shows a sketch of the drawbar giving the pertinent dimensions. Figure 1(b) shows a schematic representation of the manner in which the drawbar is to be used for the in-pile tests, and figure 1(c) indicates the manner in which the drawbar was used in the NACA tests.

Instrumentation. - The pitot-static probe with which the velocity surveys were taken could be mounted 2.87, 4, and 5 inches behind the trailing edge of the drawbar. The probe was mounted to allow manual traversing of about 0.9 inch above and 0.9 inch below the drawbar center line in increments of travel of 0.1 inch.

The manometer hookup used with the probe is also shown in figure 1(c). The probe total and static pressures were read differentially, with a side tee for static pressure measurements for calculation of local velocities. Air flow measurements were also made (as described in next section) for calculation of bulk velocities.

Air system. - A schematic diagram of the general piping layout is shown in figure 2. Service air is passed through a pressure-regulating valve and then through an orifice run consisting of an air straightener and an A.S.M.E.-type flat-plate orifice before entering the inlet tank. From the inlet tank, the air flows over the drawbar and then is discharged to the atmosphere.

The orifice and test section inlet-air temperature is measured by a thermocouple just downstream of the orifice plate.

SYMBOLS

The following symbols are used in this report:

A	free flow area of tunnel (downstream of drawbar), sq ft
D_e	effective diameter of tunnel, 4A/P, ft
g	acceleration due to gravity, 32.2 ft/sec^2
P	wetted perimeter of tunnel, ft
p	air pressure, lb/sq ft
Δp	dynamic pressure, $p_t - p_s$, lb/sq ft
R	gas constant for air, 53.35 ft-lb/lb $^\circ$F
Re	Reynolds number
t	static temperature at test section, $^\circ$R
V	velocity, ft/sec
W	air flow, lb/sec
μ	absolute viscosity of air, lb/sec-ft
ρ	air density, lb/cu ft

Subscripts:

b evaluated at bulk condition

l evaluated at local condition

s static

t total

1 evaluated for number 1 reactor segment instead of tunnel

2769

METHOD OF CALCULATION

For the tests reported herein, the local velocities were calculated from the equation

$$V_l = \sqrt{\frac{2g\ \Delta p}{\rho_l}} \tag{1}$$

where $\Delta p = (p_t - p_s)_l$ as measured by the probe and

$$\rho_l = \frac{(p_s)_l}{Rt} \tag{2}$$

The use of total temperature in place of static temperature in equation (2) resulted in negligible error for the conditions herein. The bulk velocities were calculated from measured air flows where

$$V_b = \frac{W}{\rho_l A} \tag{3}$$

The use of ρ_l for ρ_b in equation (3) incurred insignificant error inasmuch as the variation of $(p_s)_l$ across the tunnel was negligible.

The tunnel Reynolds number $(Re)_{tunnel}$ used herein is given by the equation

$$(Re)_{tunnel} = \frac{W\ D_e}{A\ \mu}$$

where $D_e = 4A/P$. The equivalent reactor-inlet Reynolds number $(Re)_{reactor}$ given herein is similarly calculated where

$$(\mathrm{Re})_{reactor} = \frac{W\, D_{e,1}}{A_1\, \mu}$$

where $D_{e,1}$ and A_1 are evaluated for the number 1 reactor segment, the values being 0.0326 feet and 0.0379 square feet, respectively. A sample calculation is given in the appendix.

2769

RESULTS AND DISCUSSION

Velocity distribution. - The ratio of local to bulk velocity plotted against probe traverse distance is shown in figure 3 for an equivalent reactor-inlet Reynolds number of 101,000 for drawbar-to-probe distances of 2.87, 4, and 5 inches. Included for comparison are data for the case where the drawbar was removed from the tunnel.

The variation of V_l/V_b at the center of the reactor segment face with drawbar-to-probe distance is given in the following table:

Drawbar-to-probe distance, in.	$(\mathrm{Re})_{tunnel}$	$(\mathrm{Re})_{reactor}$ (equivalent reactor inlet)	V_b, ft/sec	V_l/V_b (center point)
2.87	588,000	101,000	428	1.14
4	588,000	101,000	428	1.18
5	588,000	101,000	428	1.20
Drawbar removed	588,000	101,000	428	1.24

The decrease in V_l/V_b (at center point), as shown in the table, between the farthest drawbar position (5 in.) and that at a distance of 2.87 inches is about 5 percent. Comparing the value of V_l/V_b for the case with no drawbar with that for a drawbar-to-probe distance of 2.87 inches shows a decrease in V_l/V_b of only about 8 percent. Inasmuch as bulk velocity for these cases is constant, the percentage variation given is a direct measure of the variation in center-point local velocity.

The effect of Reynolds number on V_l/V_b for a fixed drawbar-to-probe distance is shown in figure 4. With a variation in equivalent reactor-inlet Reynolds number from about 35,000 to 100,000, the variation of the value of V_l/V_b for a drawbar-to-probe distance of 4 inches is only about 1 percent.

CONCLUSIONS

The results of these tests on the velocity distribution behind a General Electric drawbar can be summarized as follows:

1. At an equivalent reactor-inlet Reynolds number of 101,000 and a drawbar-to-probe (reactor inlet face) distance of about 3 inches, the local velocity at the center of the reactor segment face was about 8 percent less than the corresponding velocity found with the drawbar removed from the tunnel. 2769

2. The variation of local-to-bulk velocity ratio with Reynolds number over a range of equivalent reactor-inlet Reynolds numbers from about 35,000 to 100,000 was found to be negligible.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, November 25, 1952

APPENDIX - SAMPLE CALCULATION

Probe located 2.87 inches downstream of the drawbar and 1.25 inches from bottom wall of tunnel.

The local velocity is given by

$$V_l = \sqrt{\frac{2g\ \Delta p}{\rho_l}} = \sqrt{\frac{64.4 \times 306.5}{0.0836}} = 486 \text{ ft/sec}$$

2769

where:

$$\Delta p = (p_t - p_s)_l \quad \text{as measured by probe}$$

$$= 58.95 \text{ inches } H_2O = 306.5 \text{ lb/sq ft}$$

$$\rho_l = \frac{(p_s)_l}{Rt} = \frac{2338}{53.3 \times 525} = 0.0836 \text{ lb/cu ft}$$

The bulk velocity is given by

$$V_b = \frac{W}{\rho_l A} = \frac{1.43}{0.0836 \times 0.0400} = 428 \text{ ft/sec}$$

where:

$$W(\text{from orifice measurement}) = 1.43 \text{ lb/sec}$$

$$A(\text{tunnel area}) = 0.0400 \text{ sq ft}$$

The tunnel Reynolds number is given by

$$(Re)_{tunnel} = \frac{W\ D_e}{A\ \mu} = \frac{1.43 \times 0.20}{0.040 \times 0.1216 \times 10^{-4}} = 588{,}000$$

where:

$$D_e = 0.20 \text{ ft}$$

$$A = 0.040 \text{ sq ft}$$

The equivalent reactor-inlet Reynolds number is

$$(Re)_{reactor} = \frac{W\ D_{e,1}}{A_1\ \mu} = \frac{1.43 \times 0.0326}{0.0379 \times 0.1216 \times 10^{-4}} = 101{,}000$$

where:

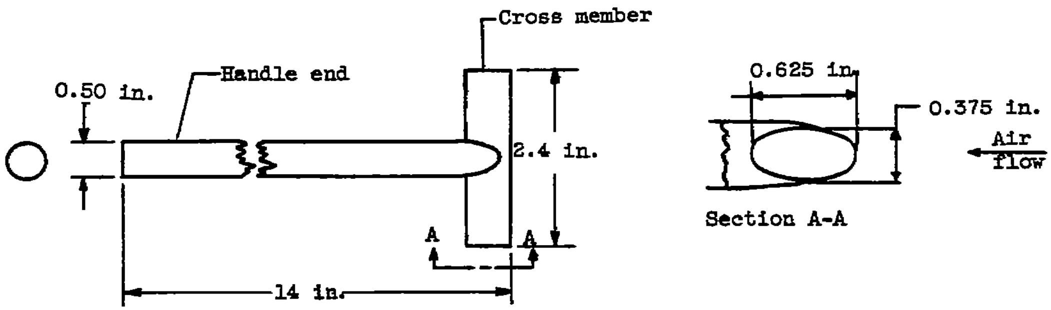
$D_{e,1}$ (number 1 reactor segment) = 0.0326 ft

$$\mu = 0.1216 \times 10^{-4} \frac{\text{lb}}{\text{sec ft}} \text{ at } 525^{\circ} \text{ R}$$

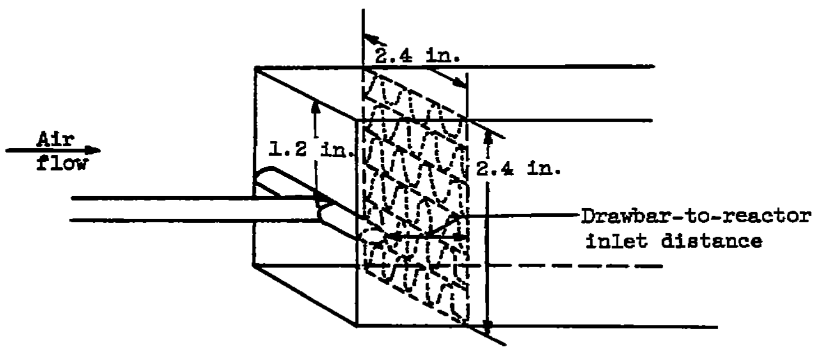
A_1 (number 1 reactor segment) = 0.0379 sq ft

2769

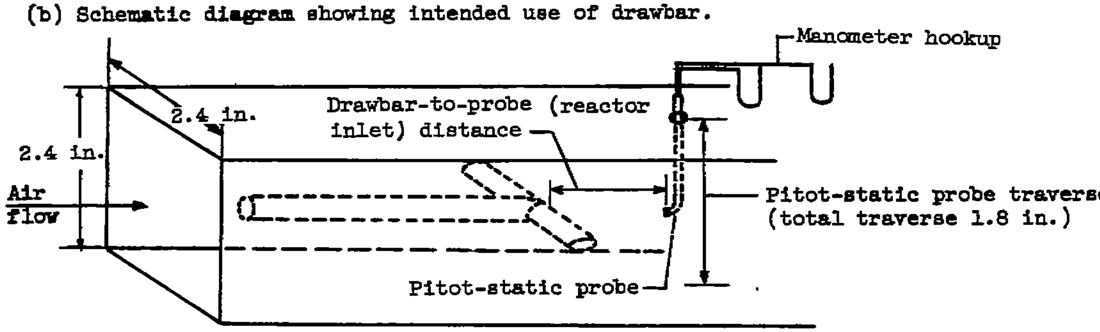
2769



(a) Sketch of drawbar.



(b) Schematic diagram showing intended use of drawbar.



(c) Schematic diagram showing method of test used herein.

Figure 1. - Drawbar and test setup.

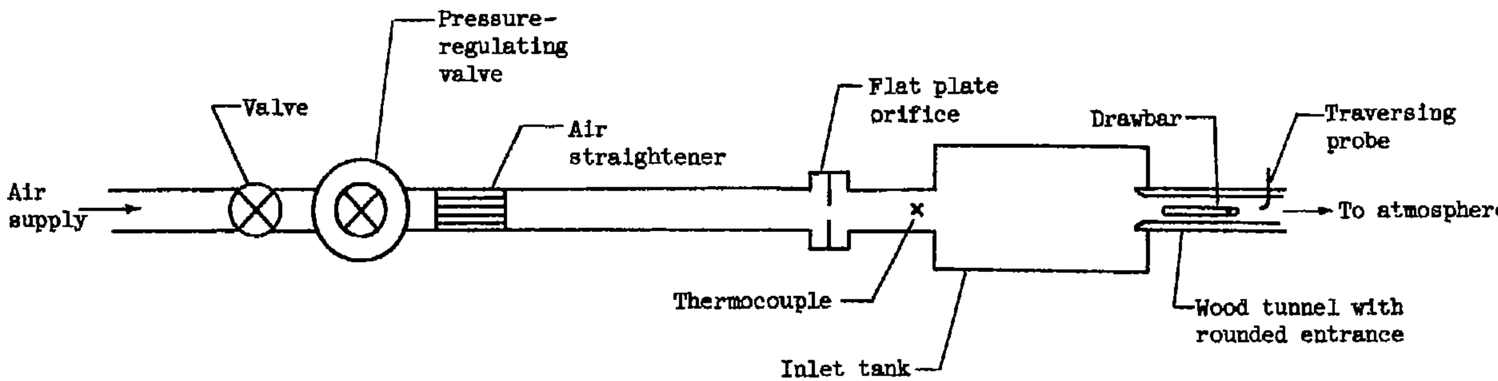


Figure 2. - Schematic diagram of general piping layout.

2769

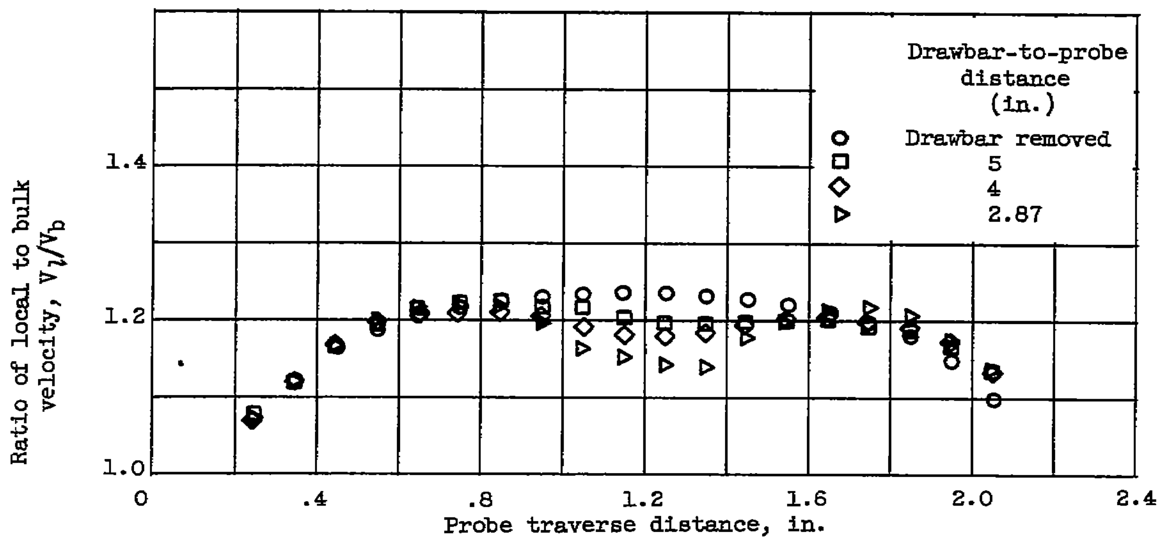


Figure 3. - Variation of local-to-bulk velocity ratio across tunnel as affected by distance between drawbar and probe (reactor inlet face). Tunnel Reynolds number $(Re)_{tunnel}$, 588,000; reactor Reynolds number $(Re)_{reactor}$, 101,000.

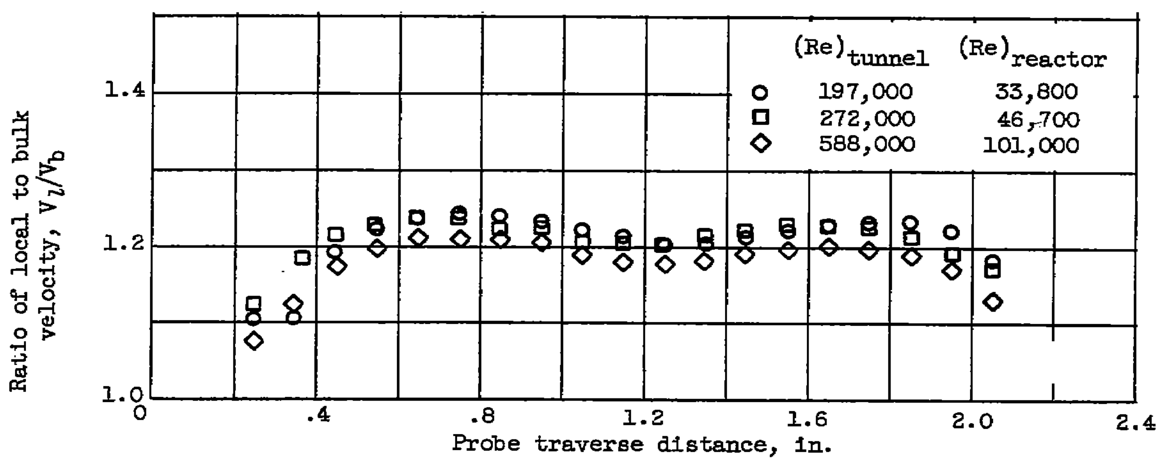


Figure 4. - Variation of local-to-bulk velocity ratio across tunnel as affected by Reynolds number. Drawbar-to-probe distance, 4 inches.